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THE METRIC SYSTEM. ITS RELATION TO MATHEMATICS AND INDUSTRY.*

By Wilmer Souder.

Mathematics as a Foundation.

Lord Kelvin has said that our understanding of a physical phenomenon is not complete until we are able to express its relations in the form of a mathematical equation. This is equally true in many other fields of activity. Even the smallest capitalist, the newsboy, is not getting all the pleasure (or worry) out of life unless he is able to accurately compare his gains and losses with those of former days and with those of his fellow workers. There is no more fundamental science than the science of mathematics, and I envy you, your position in our educational system. There is a definite yes or no to all your problems. The student who distorts the problems in any way must somewhere make a second error or inevitably arrive at the wrong answer. There is little or no occasion for an argument or back talk in your work. For the development of precision, definiteness, and confidence your subject must always remain at the top.

Success in Teaching.

As a measure of your success in this work you are in a large degree dependent upon the success of your students. The ideal measure would be to give each student an examination in applied mathematics after five years' experience in the world, then award to you the average per cent. grade as a true mark of *your* success.

My experience in teaching junior and senior students of physics at one of our largest universities has brought to my attention two examples of lack of emphasis upon certain phases of their college training. Since these will have a definite bearing on what I shall say later, I wish to take them up in detail at this time.

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* Presented at the Spring Meeting of the Association of Teachers of Mathematics in New England, May 1, 1920.

First: The absolute failure to comprehend the limitations of accuracy when applying laboratory data to mathematical equations causes hours of unnecessary work, *e.g.*, in the case of Young's modulus, where we have:

$$Y = \frac{F/A}{e/L} = \frac{FL}{Ae}.$$

It is difficult to measure the wire diameter to better than one part in 100 and when the modulus is computed, it is not uncommon to find note books with 12 significant figures instead of the usual two figures by the power of ten. Shall we call the correction of this a disillusionment of the student's conception of the accuracy of mathematical formula or shall we simply say, this is the practical limitations of the associated science? Your answer to this question may be "used as evidence against you" in the subsequent developments.

The second defect lies in the inability to interpret mathematical formula or to define the conditions without using mathematical terms: To illustrate

$$Y = \frac{FL}{Ae} = \frac{F/A}{e/L}$$

may be defined as the ratio of the force per unit cross section to the elongation per unit length, a strictly mathematical definition and from such a definition the student should see at once that reducing the diameter ½ will increase the elongation 4 times provided all other conditions remain the same, or again doubling the length of the specimen will not change the value of Y. The physical interpretation may appear less definite but is not less important: Young's modulus for any material is numerically equal to the theoretical force required to stretch a uniform bar of unit cross section to twice its original length. Manifestly the realization of this definition is impossible, although the conception is quite definite.

TEACHING THE METRIC SYSTEM.

In our consideration of the metric system of weights and measures we must insist upon the above applications and limitations. You are not teaching the metric system when you ask a pupil to convert 1 mile to millimeters, nor when you ask a student to compute the cost of 1 kilogram of meat when priced at 50 cents per pound. This is a close mathematical analogy to the "cat skinning" exercises of the gymnasium, and while it may appear to have a certain value in our educational system, there are those who feel that the time could be spent for greater profit to the student.

We object when the delivery boy starts juggling *our* packages regardless of his expert abilities as a juggler. We admire the man who can play 8 simultaneous games of chess blindfolded but question just how long he would hold down a job as advertising manager for Quaker Oats if he persisted in displaying his abilities while handicapped by a hoodwink. So it is with many of the advocates of cumbersome weights and measures. There is no use to deny the fact that commerce and production can be conducted on the present plan; but should the handicap once be removed it would be difficult to find any one (except those who have rushed into print) who would favor a return to the old shackles and it is quite possible that some of these could even point out certain statements in their printed articles which would prove their insight as to the superiority of the metric system. Stranger things than these have happened.

The actual teaching of the system is so simple and brief that scarcely more than a page is necessary. Look up your arithmetics—eliminate all the problems of 11 yds. = ? mms. and 5 gallons = ? liters; all of which are not definite enough for solution and each of which is an apology for the English system. In no sense are these to be considered teaching the metric system. After eliminating all such, see how much is left, also how direct and to the point is the real metric part of the work. Educators claim that at least 2 years are lost by burdening our students with the old cumbersome system, not to mention the discouragement and despair of many unfortunates who conclude that because they are not adept in assorting a patchwork of grains, drams, scruples, stones, carats, ounces, pennyweight, quarters, hundredweight, tons, pounds, etc., they have no mathematical ability.

By analogy I would feel like saying that the boy who can not turn cartwheels, handsprings, walk on his hands, jump stiff-kneed and do all the fancy dives, has not the ability to walk.

Teaching the metric system will automatically take care of itself. If you want approximate values, the kilometer may be thought of as a 10 minutes' walk; the meter as an arm's reach from the tip of the nose; the centimeter as a small finger's thickness; the millimeter as the thickness of a 10-cent piece (the correct gap for a Ford spark plug); the micron as the bust measure of a bacterium; the gram as 1/5 of the mass of our 5-cent piece; the liter as the volume of the soldier's canteen; the cubic centimeter as a small thimble-full; and so on.

When you name any apparent difficulty in handling the system you immediately convict yourself of negligence of the fundamentals of notation, multiplication or division; for these three operations plus the recognition of the three units—meter, liter and gram—make up the entire subject.

THE ENGLISH SYSTEM OF WEIGHTS AND MEASURES.

I shall not burden you with the tedious and complicated stories connected with the origin and development of the English system of weights and measures except to mention a few of the more important. It is generally admitted that they are not original but a modification of the systems used on the continent prior to their adoption in England. We are told that at one time 3 barleycorns made 1 inch and that 12 inches = some foot, and 3 feet = 1 yard (the length of a certain King's arm). Then in 1835 all measures were burned in a fire which destroyed the House of Parliament, after which the values were re-established as closely as possible, the fundamental unit being the bronze yard, the length of which is even today indefinite.

We must admit that these measures are romantically tied to the past and that a certain amount of patriotism and loyalty may be interwoven in their origin; but certainly they are no more ancient than the Jewish talent and have nowhere near the possibilities for a claim of divine origin which may attach to the talent.

But we find that the talent had different values for different tribes and consequently had to be discarded. Similarly we are told that the English system has suffered similar corruption, that there are 154 different units of length; and in the British corn trade alone, 200 different weights and measures. The textile and yarn situation has degenerated until it is a hopeless problem to attempt to follow all the deviations.

This subject will be treated again. Suffice it to say now, that either there is a fundamental reason for these confusions or that the English system is a failure—since the confusion has increased rather than subsided in favor of the system.

The Metric System.

The Metric System—the perfected decimal system—is the result of numerous influences. Chronologically, we find the decimal ratio first mentioned in the Book of Exodus where we are told the ephah = 1/10 homer, and again in the tithe of 1/10. The more recent developments date from the close of the eighteenth century and forced themselves upon us because, as James Watt wrote: "It is very awkward that the scientific results of various workers can not be compared." The nineteenth century's scientific developments compelled the adoption of this system among scientists just as the twentieth century's manufacturing and commercial development demand its use in efficient, progressive trade.

In 1790 Talleyrand, the French statesman, brought a bill before the French Legislature asking to have a commission appointed to investigate the possibilities of a simple and uniform system of weights and measures, designating the French Academy and the Royal Society of England as responsible for naming the commission. Because of the war situation the Royal Society failed to function and the problem was left to the French. The final outcome being a simple decimal system, without ambiguities and now confirmed by definite accurately calibrated standards copies of which are in the possession of, or available, to, every civilized nation of the earth. So perfectly have these standards been worked out in form, composition, and value, that should all traces of civilization be destroyed from the face of the earth, except the standard meter, and should a new civilization develop, the examination and study of this meter alone would be proof positive that the former civilization was of the highest order. The commercial relations of the system are shown to advantage by the chart which you see on the wall before you. (Chart explained.)

If you wish the fundamental relation, possibly the following will be sufficient; at least it won for the metrologist, Michelson, the Noebel Prize. I refer to the exact value of the meter which was established as

1 meter = 1 553 163.5 λ Red. Cd. at 15° Nor. Bar.

The red radiation of cadmium, or radiation from any element, has remained constant from the time of its discovery and is not to be considered in the class with arm lengths, foot lengths, toe widths or the distance at which one can see barleycorns.

Allow me to say at this time that the statements made in this talk are not to be considered new or original; they are in many cases a re-arrangement of previous articles and talks on this subject. Numerous writers have elaborated upon the subject and I have taken the liberty to select some of their ideas for presentation to your association.

Doubtless you have been wondering how I happened to come to Boston today. I shall be only too glad to explain. Your president asked Dr. Rosa, of Washington, to name some one to discuss the metric system before the N. E. Teachers' Association on May 1. There were three other matters to look after, in New York, Torrington, and Boston, at about this date, in which my work is concerned, so I am killing four birds with one stone, three for myself and one for your Association. I beg that you will not hold your president to too strict account.

It is because of the conviction that any step toward the adoption of the metric system is a move which will ultimately confirm its merits that I am pleased to review the situation with your organization. Boston holds a very advanced position in this activity. One of the pioneers, who thought the question out completely and advocated its early adoption, was the late Frederick Brooks of your own city. We are under obligation to him for his forceful and clear arguments in favor of these units.

THE CONFUSION OF SYSTEMS NOW IN USE (OTHER THAN THE METRIC).

There are over 150 different liquid measures in use in the world all different in name or value. There are over 100 units of mass. Sixteen of which have the same name with 14 different values for the unit, and so on with other units. Now standardization has always meant efficient production and a corresponding reasonableness in price. If you can find your fit in ready-made clothing, you are able to save a considerable amount of money. The instant you recognize a diversity of units or standards, you license the best chance for fraud. If you receive shipments from the 14 countries having different values for their pfund, the quickest and most likely plan will be to fix the selling price on the basis of the smallest mass, as the basic pfund, and who can convict the commercial agency of fraud, for isn't one pfund just as legal as another?

Until we can have uniformity and definiteness of units we shall have difficulties in regulating trade, either imports or exports. The English gallon is about 20 per cent. larger than ours. The English yard is probably not the same as ours. And our own pounds are different when you compare those used by the grocer, jeweler and druggist.

I want to give you a concrete illustration of the complications of the English system when used in its simplest form. The following problem is offered in regular form, free from catches and in units quite at home to all of you. To the first one giving the correct answer, I will present the chart which I have been using.

From 1 mile subtract

7 furlongs, 39 rods, 5 yards, 1 foot, 4 inches.

(The solution of this problem required several minutes. Incorrect answers were reported in some instances.)

OBJECTIONS TO THE SYSTEM. UNFAIRNESS AND INCONSISTENCY.

We are told that the metric system is unsuitable because its units will not divide by 2, 3, 4, 6, etc., indefinitely; whereas the 12-inch unit will. If true, then we need 12 inches=1 foot; 12

feet = 1 yard; 12 yards = 1 something, etc.; also 12 ounces = 1 lb.; 12 lbs. = 1 stone; 12 stones = 1 cwt., etc.; 12 gills = 1 pt.; 12 pints = 1 gallon; 12 gallons = etc.; 12 cents = 1 dime; 12 dimes = 1 dollar, etc. This, of course, points to the duodecimal system with all its complications.

Again it is pointed out that the metric system is a failure, since it has not displaced all others because of its inherent superiority. Listen; Weeds always tend to grow in the best gardens and have to be kept down. The vice of this city could never be kept down by the perfect virtue of your ward. Law and law enforcement are necessary and will probably be advantageous for a number of years. Now allow me to point out the defection of the English system and at the same time to intimate that such has never come to the metric despite all the prejudice, ignorance, and inexperience in its use.

Are all gallons alike? In spelling and pronunciation, yes. In capacity, decidedly no.

Are all pounds alike? In spelling, yes; in mass, no.

The same answers apply to the yard, to the mile, the ton, the barrel, etc.

You never hear of a short meter, of a large liter, or light kilogram. The units have stood the gaff and proclaim their excellence, their uniformity and permanency for all uses.

Recently the following problem appeared in the *American Machinist* and was intended to reflect on the system. In converting a simple expression to the metric values there resulted a value which was expressed in lengthy form.

1 lb. per square inch (a very simple expression) = 0.07030954 kg. per cm.^{2}, a somewhat extended and incorrect number; but observe that the value was extended to include hundredths of a milligram! A more nearly correct value is 0.07030669. Now we are often reminded that it is a poor rule that won't work both ways and that sauce for the goose should be sauce for the gander. So lets back up on the problem by converting 1 kg. per cm.^{2} to pounds per square inch carrying the value to the equivalent of .01 milligram. We get

1 kg. per cm.^{2} = 14.22339839 lbs. per sq. in. (but this decimal part is not English and must be properly expressed in the usual units).

= 14 pounds (avoirdupois, not apothecaries).
3 avoirdupois ozs.
9 drams
5.1950 grains.

You may draw your own conclusions as to the more simple method of expressing the similar values, as to the sincerity and motives of one who will resort to such extremes to confuse his readers, and as to the weakness of the case when it becomes necessary to imply such ignorance and stupidity on the part of the readers.

Again we are told that metric values will introduce fractions in manufacture; this is not strictly true, for the fractions are already there. Take for example the innocent simple half-inch pipe thread tap. Watch closely, many have failed to locate the half-inch value. For this tap you use a 0.6875 inch drill and the two diameters used in thread notations will be (for the finished thread) 0.8257 inch and 0.7342 inch, whereas the metric values would be 17.46, 20.97 and 18.65 mm. respectively.

Have you ever heard the statement: "The inch is a most convenient unit"? I have. Very well, suppose we look for some visible manifestations. Is this an inch? (measures numerous articles in sight) or this? The values are 1 cm., 2 cm. and this 4 cm. and this 1 cm. Does any one see anything in this room which is 1 inch. Surely there must be something exactly 1, 2, or 3 inches in dimension if the unit is so convenient. (Nothing discovered with exact inch values.)

Most materials are manufactured on the basis of a template pattern or a "go" and "not go" system. This means that the model is made up and allows a certain tolerance. A tolerance of one thousandth of an inch is considered accurate work on many items of the shop. This would be expressed as 0.9995 to 1.0005 inch. The metric equivalents of these numbers do not look any more cumbersome nor any more vicious and are just as easily laid out on a measuring device.

Many manufacturers have been talked into believing that the system will play havoc with their production rate and consequently we have a list who insist that no changes be made. This is not unusual. There were many objections to the Pure Food Laws. England still objects to a decimal system of currency and a majority of the taxpayers universally object to the tax rates for the next year. I have in mind a person who objected to the Rural Free Delivery System of the Post Office Department because it gave a man a job at $600 per year, and another who objects to all vaccinations, X-rays, and surgery, saying that if the Creator wants any foreign things in the body, He'll see to it that they go there and that it is useless to try to violate His will by removing them.

We must not listen to the complaints of the chronic objectors nor delay progress because of an imaginary fear that something may happen if advance steps are taken by our civilization. The advance step often furnishes the cure for thousands of former difficulties.

Objection is often raised on the ground that the metric system does not adapt itself to our foreign trade, attempts have been made to show that the consuls and foreign agents of the various countries of South America object to its use. The *Decimal Educator* for December, 1919, clears up this polluted atmosphere very nicely by giving over 20 letters from these countries' representatives and in many instances they reveal deliberate misrepresentations on the part of the metric objectors. All are in favor of the system and practically all comment upon the success of the system.

Again we are told that the mental capacities are limited, that certain classes are of (low?) a fixed mentality and can comprehend 2, 3, 4, 6, and possibly 8 but not 10 or 100; *i.e.*, the division of $1/10$ or $1/100$ are not comprehended as is the case of $1/8$ or $1/6$, etc. I fail to grasp the point, I feel it is an unjust reflection and that 10 cents as $1/10$ of a dollar or 1 cent as $1/100$ of a dollar is even more definite than $1/8$ or $1/6$ of a dollar. Try short changing a customer 1 cent on the dollar and see if he comprehends 1 in 100.

Proofs of the failure of the system would be: A slurring or modification of the values of the standards, the rejection by *important* countries or manufacturers after trial or the evidence that computations are more laborious.

The objections remind us of a story told about the railroad yard master who was looking for a spare engine to move a train of cars. The first engine was of the largest battle-ship type and as it stood near the cars said: "Too-heavy! too-heavy!—too-heavy!" The master passed to the next, a speedy freight engine which said: "Can't do it!—can't do it!—can't do it!" There being only one engine left (a little dinkey switch engine) he ordered it hitched up. The little fellow, quite willing to try, started up the grade saying "I—think—I—can!—I—think—I can! I think I can!' (and as it went over the hill changed to) "I thought I could! I thought I could! I thought I could!" and I dare say this will fit the manufacturing situation more closely than we think. The manufacturer's foremen are not deficient in brains, and the abilities shown in setting lathes and shapers for the innumerable complicated parts of machine guns, torpedoes and motors lead us to infer that they are not too stupid to apply a set of simple translation gears and scarcely notice the effort required.

The scientists have solved the difficulties and are universally using the metric system. No one questions but that it is the best for their work and that it is a success; that the language and constants of scientific research are universal. English and American scientists were able to step into the French War Laboratories and begin assisting in the work within the hour. Since a majority of your students will come in contact with the important scientific developments of the age; it is worth your while to make them experts in the metric system; if for no other reason than that they may be capable of comprehending and using opportunities of the scientific world.

Another rather queer objection which is often offered is a statement that the confusion in the English system is due to the attempt to adopt the metric, etc. Such objections arise from a too literal interpretation of Mark Twain's advice: "Get your facts first; later you can distort them as much as you please."

Let me close by comparing the confusion due to the metric system to the boy's definition of salt: "Salt is what spoils your potatoes when you don't have any on them."

WASHINGTON, D. C.